

## Nuclear Energy Chemistry Questions with Solutions

**Q1:** Nuclear fusion is the phenomenon of \_\_\_\_\_

- a) Heavy nucleus splitting
- b) Heavy nuclei combining
- c) Light nucleus splitting
- d) Light nuclei combining

**Answer:** d) Light nuclei combining

Explanation: Nuclear fusion occurs when two or more lighter nuclei combine to form a single stable and heavy nucleus.

**Q2:** In which of the following processes are Neutrons emitted?

- a) Nuclear fission
- b) Inverse beta Decay
- c) Spontaneous Fission
- d) Nuclear fusion

**Answer:** a) Nuclear fission

Explanation: The splitting of a heavy nucleus into two or more lighter nuclei is known as nuclear fission. This results in a loss in mass, as well as exothermic energy and neutron emission. Fission elements are nuclei that emit two to three neutrons per nucleus.

**Q3:** In the Proton cycle, the hydrogen and deuteron fuse to form \_\_\_\_\_

- a) Deuteron
- b) Helium – 3
- c) Helium – 4
- d) Tritium

**Answer:** b) Helium – 3

Explanation: The process is as follows:  ${}^2\text{D} + {}^1\text{H} \rightarrow {}^3\text{He} + \text{Q} \times 2$   
The deuteron combines with a proton to yield Helium-3.

**Q4:** Why neutrons with lower energy should be capable of causing fission?

- a) For sustained reaction process
- b) For faster reaction process
- c) For Safety purpose
- d) In order to not waste the nuclear fuel

**Answer:** a) For sustained reaction process

Explanation: The initial high kinetic energy of a fission neutron is reduced due to collisions with other nuclei. Thus, even lower-energy neutrons should be able to cause fission in a long-term reaction. Only neutrons may cause a sustained reaction because each neutron absorbed by fission releases two or three neutrons.

**Q5:** What would be the effect of a nuclear holocaust?

- a) Nuclear Summer
- b) Nuclear Spring
- c) Nuclear Winter
- d) Nuclear Autumn

**Answer:** c) Nuclear Winter

Explanation: The radioactive waste is expected to hang like a cloud in the earth's atmosphere in the event of a nuclear holocaust. The sun's radiation will be absorbed, resulting in a nuclear winter.

**Q6:** Mention the types of Nuclear Reactions.

**Answer:**

Inelastic scattering: When energy is transferred, this phenomenon is called inelastic scattering. It occurs over the energy threshold.  $E_t = ((A+1)/A) * \epsilon_1$ , where  $E_t$  denotes the inelastic threshold energy and 1 denotes the energy of the first excited state.

Elastic Scattering: Elastic Scattering happens when energy is transferred from a particle to its intended nucleus. It is the most important method for slowing neutrons. The total kinetic energy of any system is conserved in the case of elastic scattering.

Transfer Reactions: Transfer reactions are defined as the absorption of one particle followed by the discharge of one or more particles.

Capture Reactions: Capture reactions happen when nuclei capture neutral or charged particles and then emit  $\gamma$ -rays. Neutron capture processes let out radioactive nuclides.

**Q7:** How are nuclear reactions different from chemical reactions?

**Answer:**

- Chemical reactions break and build bonds between two separate atoms, whereas nuclear reactions produce particles or rays from the nuclei of a single atom.

- Chemical reactions cause atomic rearrangements, although the atoms themselves stay unaltered. On the other hand, nuclear reactions involve a change in nuclear composition and hence a transformation of one type of atom into another.
- Nuclear reactions involve electrons, protons, and neutrons instead of valence electrons in chemical reactions.
- Small energy shifts occur in chemical processes. However, nuclear reactions result in significant energy changes.
- Temperature, reactant and product concentrations, pressure, and the presence of catalysts are all elements that influence the pace of a chemical reaction. Nuclear processes, on the other hand, are unaffected by any of these conditions, and their rates can range from milliseconds to millions of years.

**Q8:** Define nuclear transmutation. What causes nuclear transmutation?

**Answer:**

The conversion of one chemical element or isotope into another chemical element is known as nuclear transmutation. Nuclear reaction or radioactive decay can both be used to create transmutation.

Transformations can occur as a result of nuclear decay of radioactive isotopes or neutron capture. Neither procedure requires a change in the atom's element. An atom gets transmuted into an atom of a different element when the number of protons in it is changed.

The atomic number may remain unchanged after a neutron capture, but the quantity of nucleons is always increased. The isotope number changes, but the change is not chemical because the atom remains the same.

In unstable, radioactive elements, natural transmutation occurs when they decay into a series of other elements until a stable element is produced. As a result, uranium 238 spontaneously transmutes into stable lead 206.

**Q9:** Mention the factors affecting stability of Nucleus.

**Answer:**

The following factors have an effect on nucleus stability:

#### 1. Neutron-proton Ratio or $n / p$ Ratio

It is the most important aspect in determining nucleus stability. The nuclei in the zone of stability, also known as the belt of stability, are stable. Above this zone, nuclei with a greater n/p ratio undergo  $\beta$  – emission to reach the stability zone.

## 2. Binding energy

When a nucleus is produced from its constituent nucleons, it releases energy. The higher the BE per nucleon, the more stable the nucleus. The maximum BE per nucleon for Fe is 8.8 MeV. As a result, it has the highest stability.

## 3. Packing fraction

It is the relative mass defect measurement.

*Packing fraction = isotopic mass – mass no / mass no.  $\times 10^4$*

It can have a positive, negative, or zero value. Positive packing fraction nuclei are extremely unstable. Fe has the lowest packing fraction and H<sub>2</sub> has the greatest.

## 4. Magic numbers

These numbers are referred to as magic numbers because nuclei with 2, 8, 20, 28, 50, 82, and 126 protons or neutrons are stable.

Even-numbered  $p^+$  and  $n^0$  nuclei are more stable than odd-numbered nuclei.

**Q10:** (i) Calculate the number of electrons which will together weigh one gram.  
(ii) Calculate the mass and charge of one mole of electrons.

**Answer:**

(i) Mass of an electron =  $9.1 \times 10^{-28}$  g

$9.1 \times 10^{-28}$  g is the mass of = 1 electron

$\therefore$  1.0 g is the mass of =  $\frac{1}{9.1 \times 10^{-28}} = 1.098 \times 10^{27}$  electrons

(ii) One mole of electrons =  $6.022 \times 10^{23}$  electrons

Mass of 1 electron =  $9.1 \times 10^{-31}$  kg

Mass of  $6.022 \times 10^{23}$  electrons =  $(9.1 \times 10^{-31} \text{ kg}) \times (6.022 \times 10^{23}) = 5.48 \times 10^{-7}$  kg

Charge on one electron =  $1.602 \times 10^{-19}$  coulomb

∴ Charge on one mole electrons =  $1.602 \times 10^{-19} \times 6.022 \times 10^{23} = 9.65 \times 10^4$  coulombs

**Q11:** Mention the applications of Radioactivity.

**Answer:**

### 1. Estimation of Age (Dating Technique)

**(i) Carbon dating technique:** It is used to evaluate wood, animal fossils, and other materials. It is based on the ratio of  $C^{14}$  to  $C^{12}$  in living species, which remains constant but drops in deceased samples. The age is calculated by comparing these two.

**(ii) Uranium dating technique:** Uranium-series dating, as the name implies, uses the radioactive decay of uranium to determine an age. When uranium decays, it undergoes a series of transformations before reaching a stable isotope. For instance, uranium 238 decays to uranium 234, which decays to thorium 230.

### 2. Medicinal Use

Many diseases are diagnosed and treated with radioisotopes. These can be utilised in three different ways: In Vivo studies, In therapeutic procedure (to cure diseases), and Imaging procedure.

Radioisotopes are also widely used in industry and agriculture to determine reaction mechanisms.

**Q12:** The half life period of a first order radioactive decay of an element is 5 days. What is the time (in days) taken for 8g of this element to decay to 1g?

**Answer:**

The rate constant for a first-order reaction is calculated by using the following:

$$k = \frac{0.693}{t_{(1/2)}}$$

$$k = \frac{0.693}{5} = 0.1386 \text{ day}^{-1}$$

Now, the formula for the time,

$$t = \frac{2.303}{k} * \log \frac{8}{1}$$

$\therefore t = 15 \text{ days}$

**Q13:** Define Radioactive Disintegration. Mention the methods of Radioactive Disintegration.

**Answer:**

Radioactive disintegration is the process of converting one radioactive nucleus into another by the production of  $\alpha$ ,  $\beta$  and  $\gamma$ -rays.

Rutherford and Soddy proposed it in 1903.

$\gamma$ -rays are secondary consequences of radioactive disintegration, meaning they are only emitted after  $\alpha$ - and  $\beta$ -rays.

**Methods of Radioactive Disintegration are as follows:**

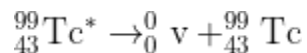
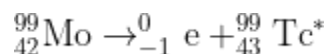
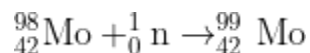
- **Alpha ( $\alpha$ ) Decay:** Emission of an  $\alpha$ -particle decreases the atomic number by 2 units and mass number by 4 units.
- **Beta ( $\beta$ ) Decay:** Emission of a  $\beta$ -particle increases the atomic number by 1 unit but does not affect the mass number.

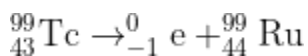
Isotope is created through the emission of one  $\alpha$  and two  $\beta$ -particles.

- **Gamma ( $\gamma$ ) Decay:** The atomic number and mass number are not affected by the emission of  $\gamma$ -rays.

**Q14:** Technetium-99 is prepared from  $^{98}\text{Mo}$ . Molybdenum-98 combines with a neutron to give molybdenum-99, an unstable isotope that emits a  $\beta$  particle to yield an excited form of technetium-99, represented as  $^{99}\text{Tc}^*$ . This excited nucleus relaxes to the ground state, represented as  $^{99}\text{Tc}$ , by emitting a  $\gamma$  ray. The ground state of  $^{99}\text{Tc}$  then emits a  $\beta$ -particle. Write the equations for each of these nuclear reactions.

**Answer:**

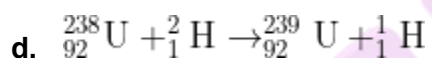
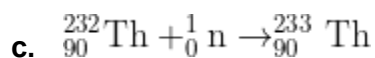
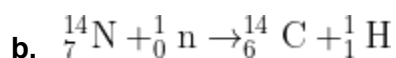
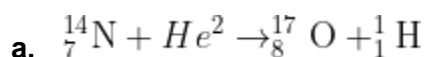




**Q15:** Write a balanced equation for each of the following nuclear reactions:

- the production of  ${}^{17}\text{O}$  from  ${}^{14}\text{N}$  by  $\alpha$  particle bombardment
- the production of  ${}^{14}\text{C}$  from  ${}^{14}\text{N}$  by neutron bombardment
- the production of  ${}^{233}\text{Th}$  from  ${}^{232}\text{Th}$  by neutron bombardment
- the production of  ${}^{239}\text{U}$  from  ${}^{238}\text{U}$  by  ${}^2_1\text{H}$  bombardment

**Answer:**



## Practise Questions on Nuclear Energy

**Q1:** Who invented nuclear fission?

- Rutherford
- Otto Hahn
- Hans Bethe
- Marie Curie

**Answer:** b) Otto Hahn

Explanation: On December 17, 1938, German Otto Hahn discovered heavy metal nuclear fission, which was theoretically explained by Lise Meitner and her nephew Otto Robert Frisch in 1939. Frisch named the process after biological division of living cells.

**Q2:** Mention the applications of Nuclear Energy.

**Answer:**

- Nuclear technology
- Nuclear medicine
- Biological Experimentations
- Engineering Projects

- Scientific Investigations
- Neutron Activation Analysis
- Nuclear Technology is used in Industries
- Environmental uses of nuclear technology
- Agricultural uses of nuclear technology
- Medical diagnosis and treatments

**Q3:** Define Nucleons and Nuclear Forces.

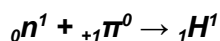
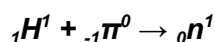
**Answer:**

Nucleons are protons and neutrons that reside in the nucleus, and nuclear forces are the forces that hold them together.

These are short-range forces that operate over extremely short distances (1 fermi =  $10^{-15}$  cm).

The electrostatic forces are 1021 times stronger than these forces.

The rapid interchange of nuclear particles known as mesons holds  $n^0$  and  $p^+$  together (discovered by Yukawa). Mesons can be charged positively ( $\pi^+$ ), negatively ( $\pi^-$ ), or neutrally ( $\pi^0$ ).



**Q4:** Define Accelerators.

**Answer:**

Projectiles are propelled by accelerators. Linear accelerators, cyclotrons, and synchrotrons are common accelerators.

Proton accelerators are used in synchrotrons. Neutrons are the best projectiles because they are neutral, but protons and deuterons are superior projectiles because they are monopositive (dipositive).

**Q5:** Write in brief each of the following:

- nucleon
- $\alpha$  particle
- $\beta$  particle
- positron
- $\gamma$  ray
- nuclide

**Answer:**

- a. Protons and neutrons in a nucleus are referred to as nucleons.
- b. ( $\alpha$  or  ${}^4_2\text{He}$  or  ${}^4_2\alpha$ ) high-energy helium nucleus; a helium atom with two protons and two neutrons that has lost two electrons.
- c. ( $\beta$  or  ${}^0_{-1}\text{e}$  or  ${}^0_{-1}\beta$ ) high-energy electron
- d. Positron is the antiparticle of the electron; it has the same properties as an electron except it has a positive charge.
- e. ( $\gamma$  or  ${}^0_0\gamma$ ) high-energy electromagnetic radiation with a short wavelength and wave-particle duality.
- f. Nucleus of a particular isotope is nuclide